Si on the mica surface was detected, and then it decreases at fluence 1×10^{14} ions/cm^2. In addition, the content of element O on the surface is increasedat this fluence. It could be concluded that the O element detected on mica surface generally can be divided into two parts, the first one is from the pristine mica sample, and the second is the O element captured from the air. The activated bonds could capture O around as the swift heavy ions destroyed the bonds between K^+ ions and aluminosilicate sheets.

In conclusion, the chemical composition of mica was alternated by the irradiation of heavy ions. The investigation indicated that the surface of mica was cleaved, and the heavy ions destroyed the bonds that caused the decreasing of elements K and Alat the rangeof 1×10^{11} to 1×10^{14} ions/cm^2. In addition, it also has a great influence on the content of elements Si and O.

3 - 37 Irradiation Experiment of ODS Ferritic Steels with 122 MeV Ne Ions at HIRFL-SFC

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The Sector-focused Cyclotron (SFC) at HIRFL is a useful tool to simulate radiation damage in materials candidate to advanced nuclear reactors, because it can supply heavy ions ranging from ^{12}C to ^{238}U in high beam density, with kinetic energies typically in the range 1～10 MeV/u, which can penetrate pure iron up to 31 micrometers in depth and produce atomic displacement at a rate around 0.1 dpa/h. To meet a variety of demand for irradiation of candidate materials, we recently developed a new chamber at the terminal of SFC. The new chamber includes an energy degrader which enables a uniform distribution of atomic displacement damage and injected ions within the projective range in specimens, a cooling (liquid nitrogen) stage, a hot (up to 600 ℃) stage for specimens of materials. On both stages up to five specimens can be mounted at once for irradiation. An overview of the chamber and a SRIM estimate of the depth distribution of atomic displacement damage by 122 MeV Ne ions in Fe-base specimens are shown in Fig. 1. The new chamber enables the simulation of irradiation conditions of materials at both low temperatures like near the superconducting coils in fusion reactors and at high temperatures at the first wall in fusion reactors or near the cladding of nuclear fuels in fast breeder reactors.

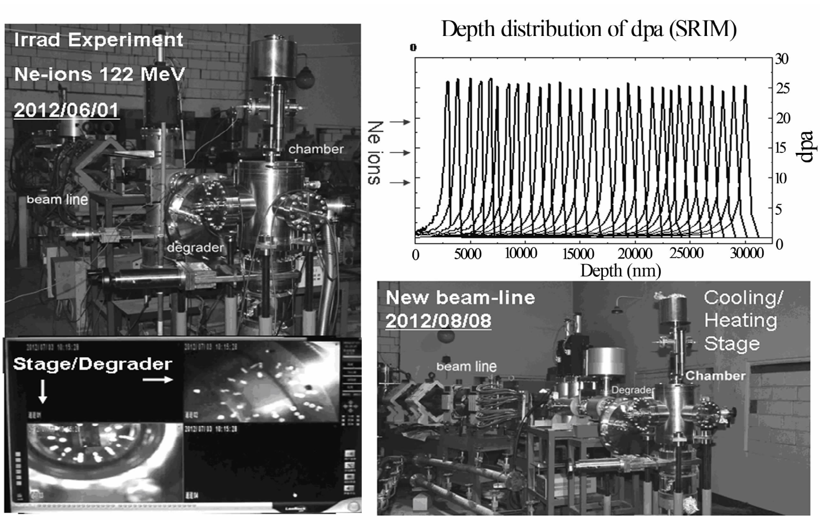

Fig. 1 Overview of the new chamber with an energy degrader at HIRFL-SFC, with an inset showing a SRIM estimate of the depth distribution of dpa in Fe-base alloys.

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The installment and tests of the new chamber was accomplished in May, 2012. In early June the chamber was used in an irradiation experiment of specimens (3 kinds of ODS ferritic steels, 2 kinds of ferritic/martensitic steels) at HIRFL-SFC using Ne ions with a kinetic energy of 6.17 MeV/u. According to our previous work (Zhang et al, J. Nucl. Mater. 375(2008)185; 386(2009)457), Ne ions can be effectively used to simulate helium implantation and meanwhile can produce a higher level of atomic displacement damage (in dpa) in the specimens. A uniform distribution of Ne concentration and atomic displacement damage (in dpa) was produced from the near surface to a depth about 31 micro-meters in the specimens, as shown by the SRIM estimate in Fig. 1. In some specimens a uniform distribution throughout the whole thickness of 60 micro-meters was produced by irradiation from both sides. Several dose levels ranging from 600 to 1600 appm of Ne concentration, corresponding to 0.5, to 1.3 dpa were approached.

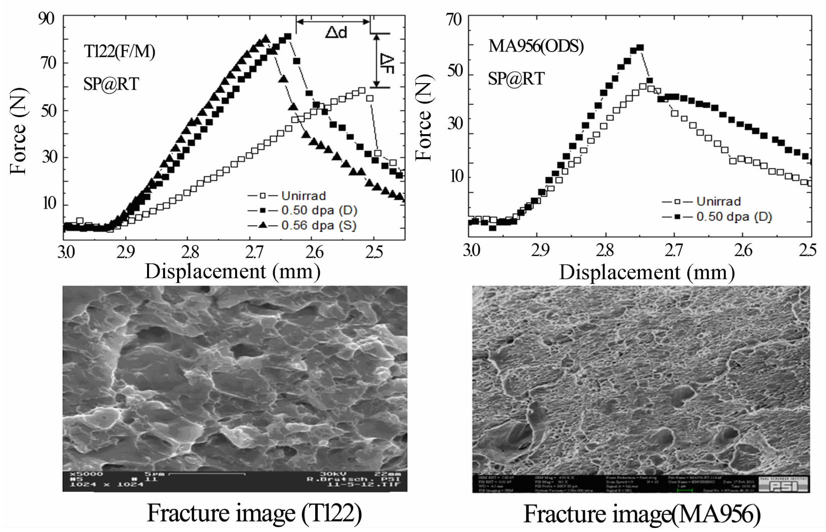

Fig. 2 Load-displacement curves and corresponding SEM images of the fractured areas of two steels, grade 122 ferritic/martensitic steel (left) and ODS ferritic steel (right).

Tests of the mechanical properties were carried out using a special equipment of Small-ball Punch Test in Paul Scherrer Institut (PSI). Disks with 3 mm in diameter of each kind of the steels were tested with Small Punch test at room temperature and 500 ℃, respectively. The obtained load-displacement curves of two steels in different conditions (un-irradiated or irradiated) are shown in Fig. 2, together with images of the fractured area with SEM. The results show that there is already a hardening and an embrittlement in the conventional Ferritic/Martensitic steel (T122), while less hardening and embrittlement were observed in the ODS ferritic steel (MA956). The observation with scanning electron microscopy (SEM) supports the results of the Small Punch Test by showing that the fractured area of MA956 is more ductile than that of the grade 122 Ferritic/Martensitic steel, indicating that the ODS ferritic steel MA956 is more resistant to the atomic displacement damage and the Ne atom deposition. Moreover, the test at a high temperature of 500 ℃ shows that ODS ferritic steels do not exhibit observable loss of ductility even to the highest dose level (1600 appm Ne, corresponding to 1.3 dpa), indicating that the ODS ferritic has a higher resistance to helium embrittlement, probably due to the trapping of helium atoms at the oxide/substrate interfaces and thus the reduction of transport of helium atoms to grain-boundaries. Results of the present work show the advantage of ODS ferritic steels which are proposed to be used in harsh environments with strong irradiation like in fast breeder reactors or in fusion reactors. An investigation with transmission electron microscopy (TEM) is being carried out to know in detail the defect accumulation and evolution in the steels and to build up a correlation of mechanical properties with microstructures.